# A dynamic life of cause : a concept and models using for computer-assisted choreography

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**Abstract**
The authors propose a series of physics-based models relating to dance verbs. These physics-based and dance verb-relating models generate dance movements dynamically instead of reserve of motion data. In terms of movement representation, these models are useful for computer-assisted choreography and for character animation. In terms of movement understanding, these models based on physics are useful as well by manipulating the cause-effect relation of modeling. In other words, these models can be a kind of predictive models for human behavioral research. In the article, the authors explain mainly the concept of "a dynamic life of cause" relating to both physics-based models and dance verbs. Furthermore, the authors propose composing "a dynamic life of cause" for movement composition.

**Introduction**
Badler [1] summarized several approaches about digital human motion representations. Herbison-Evans [5] reported various uses of computer graphics in dance: dance notation, choreography, live performance, movement understanding, movement teaching and digital movement representation. The authors are involved in generating computational dance movements by mass-interaction modeling that can be regarded as digital representation of movement at first appearance.

While most approaches of physics-based animation focus on algorithmic improvement or on multimodal interactive application, this article focuses more on the meaning of the articulation between dance and physical knowledge. For example, contraction/release state of body is represented by a thin/thick spring. Another example, we take care of the cause-effect relation in dynamics to represent what occurs within dancer's mental motor control and physical body. In the results, the motion qualities — light-strong, direct-indirect, sudden-sustained, according to Laban effort-shape theory [8] — can be achieved by controlling amplitude, phase and frequency in our models. The physics-based models that we create take account of dance knowledge toward movement understanding.

With the purpose of computer-assisted choreography, we developed a library of physics-based models according to dance verbs [6, 7]. After the construction and manipulation through the physics-based models, this article discusses the difference between "seeing" and "doing" dance movement, and then extract a concept of what can evoke each dance verb dynamically. "A dynamic life of cause" implying the effect of pre-movement, is named thus. More precisely,

we integrate the concept of pre-movement from dance knowledge into the procedure of modeling.

**Argument 1: Seeing/Doing vs. Figure based/Dynamics based**

Animating characters by computer animation has a significant similarity with making dance that both create movement. Nevertheless, the developing domain of computer-assisted choreography is still far from profound. Calvert and others [3] inferred that: "it reflects the reluctance of dancers and choreographers to let anything get between them and the live kinaesthetic experience". It also reflects the fact that there is some misleading thinking in the developing technology for computer-assisted choreography. Perhaps the computing thinking is not intuitive, not in sufficient accordance with dance thinking.

We suppose that the gap is coming from different cognitions of dancer and the audience. The audience perceives the resulting motion in visual, spatial and temporal ways; that is to say, the motion is composed of "many gestures". Dancer concerns his energy within body and his interaction with environment (gravity, floor, partner, etc) to provoke motion. Here, we propose roughly the difference between seeing and doing motion. This gap leads to two extremes in motion generation: computer produces motion from the result; dancer produces motion from the cause.

Most computer-assisted choreography systems are founded on kinematical based animation including key-framed and motion-capture based. For both key-framed and motion-capture based animation, computer always needs a predefined and explicit motion, which is less suited for computer-assisted choreography. In other words, such methods may not be considered to assist a choreographer to design and create dance motion as with the usual high-level metaphoric way (implicit description): "be as a leaf falling to the floor lightly" or "be as an apple falling to floor strongly". They cannot focus on the style of the motion or on the metaphoric conditions to create it, but explicitly describe the motion itself. Therefore, the developed system focusing on kinematical based gestures is generally less suited for assisting choreography.

Instead of this, dynamics based approaches (physics-based animation) are able to generate realistic or plausible motions automatically. However, the difficulty of physics-based animation is the delicate problem of the balance between motion control, complexity of character structure and computing cost. Our approach uses "mass-spring based modeling" which has the advantages of computing efficiency and offers a powerful interaction with the environment. More details about the simulation system can be found in the papers [4, 9]. On account of this, we circumvent the computing problem. The remaining challenges are to control a desired motion and to explore the relationship between dynamics and dance.

**Proposition 1: A Dynamic Life of Cause**

To solve the challenge of controllability, we propose the idea of "modular design" according to each kind of movement, i.e. dance verbs. Among these dance verb-relating models, complex character structure and complete motion are simplified and refined by "the just necessary masses" and "the essential interactions". Thanks to the use of the simplification procedure, we can focus on the interaction and connection through dance movement and take advantage of the simplest computing technique.

While a complex character structure is deconstructed in a "mass-spring based modeling", the material skeletons and articulations, do not exist anymore. Instead, this reduced number of interacting "masses" represents either materials (e.g. visible skeletons and limbs) or functional (e.g. invisible interaction connecting right hand and left leg due to balance) components. Here, it differs from classical uses of physical modeling to represent exactly the properties of matter (e.g. using mass-spring modeling to represent the deformation of skins). Because of this, we are concerned only in the "interaction" through all the action.

In dancer's viewpoint about dynamics, especially for contemporary dance, every action comes from a cause that destroys the initial balance. For most dancers, there must be a cause, which may be a change of the gravity center or a loss of balance, to provoke all the movements. Then, this cause triggers the remaining motion. In the end, the body will find another new balance. Consequently, the process of dance has a single common dynamic formula: "preparation-action-recovery". Malkovsky called this pattern "trigger-let go and relax- new balance" and referred it to the principle of causality, which serves itself in a state of "economy of effort" [2].

In our approach, all the physics-based and dance verb-relating models are created according to the following procedures:

1. Finding out the "motor locus" and initiating the energy into this motor (the birth of cause)

2. Generating the motions from the "motor" (the growth of cause)

3. Decreasing influence of the motor and finding out a new balance (the death of cause).

Figure 1 (see page 3) shows "a dynamic life of cause" of a jumping motion. If we add an initial velocity to the gravity center, causing it to fall down, the driving motor thus has a kinetic energy. If we add a potential energy to the squat state, the driving motor would thus have the ability "to jump". Therefore, in "the birth of cause", driving motor could be designed by defining the potential energy (e.g. a spring at compressed state) or the kinetic energy (e.g. a spring having velocity at equilibrium state). Then, "to rebound" is affected dynamically for different levels of landing. A strong landing with a full rebounding comes from less energy extinguishing (less damping). In contrast, a light landing with some vibration of knee comes from diminishing energy (more damping).

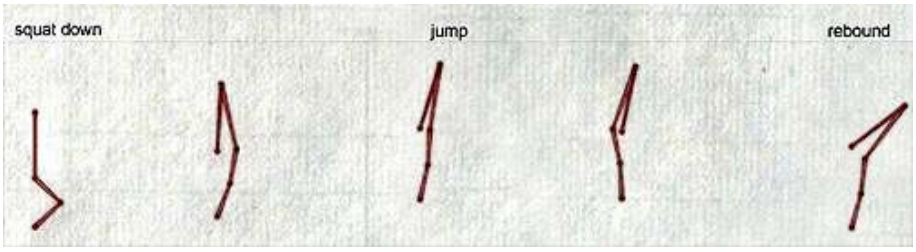


**Figure 1: A dynamic life of cause. To squat down is the birth; to jump is the growth; to rebound is the death.**


Indeed, generating dance movements with the help of "a dynamic life of cause" is very special because it is concerned with movement understanding. Instead of explicit description of the resulting motion, it is another choice to describe motion by its cause. In addition, it is in accordance with the philosophy of contemporary free dance: "Understanding the directions for a free dance performer stems mainly from the qualities and energy of the movement rather from spatial criteria" [2].

**Argument 2: Motion Composing or Cause Composing?**
Furthermore, we wonder how to improve on motion composing. Considering coherence, "qualitative transition" is relatively ignored in comparison with movement transition. That is to say, people compose two adjoining motion trajectories at position level or even at velocity level, for a smooth transition in kinematics. However, the logic of composing of the two actions is disregarded; some important details are also lost during movement transition, e.g. a delicate transfer of gravity center, a preparation of the next action.

Moreover, people disregard whether the qualities of the two adjoining movements are coherent; if not, there should be a "qualitative transition". While one skilled dancer interprets a dance repertoire, his/her coherent personal quality is injected into movements consciously or unconsciously to retrieve the missing details. Nevertheless, do computers recover the missing details after motion editing and composing? A delicate interrogation is that reuse of motion data is exploited for its primitive quality. It is not only an ideological argument, but indeed, qualitative control is disregarded in comparison with motion control. Instead of motion composing, we focus on "cause composing" referring to physical body state and its cause, in order to improve qualitative control.

**Proposition 2: Causes' Dynamic Lives**
Inherited from "a dynamic life of cause", our methodology is progressing on bringing the death of one cause into the birth of another cause. In other words, we attempt to compose "cause" and take care of its "body state" at the same time.

For instance, we choose a series of jumping models such as: jump, leap, hop, sissonne and assemblé [6]. By initiating a kinetic energy into one foot or two feet, we decide to take off with one foot or two feet. By designing the parameters of legs' viscous-elastic interactions between pelvis and foot, the two legs will have muscles with different strength, which means that the two legs have different potentials. Thus, it can lead two legs to land together or not. By composing with two legs' take-off and landing, five basic jumping models can be achieved: jump from both feet to both feet; leap from one foot to the other foot; hop from one foot to the same foot; assemblé from one foot to both feet; sissonne from both feet to one foot.

All of these jumping models are provoked by their squat states (the birth of cause). Then, they achieve their movement at the rebound states (the death of cause) that can provoke another

jumping motion dynamically as shown in figure 2 (see page 4). In such special case, it is logical to compose the jumping models because all the varieties of jumping action are based on a typical motion pattern opposing to gravity. In addition, these jumping models, which have the same structure and the same inertia, can maintain, in part, the quality coherently

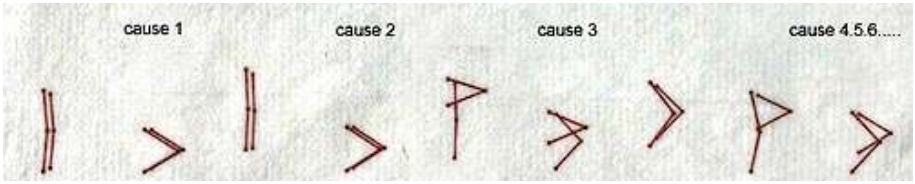


**Figure 2: Composing of dynamic causes. Cause 1 leads to jump; cause 2 leads to sissonne; cause 3 leads to leap; then cause 4, 5, 6, etc.**


Nevertheless, in a usual case, we need to find out the logic in dynamics to compose sequential dance verbs. Our proposed concept for motion composition is very particular because we are attempting to compose oscillations in the motor (the cause). That is to say, in analogy to musical playing, we compose different ways to "oscillate" instrument. In such case, the physical body is regarded as an acoustic instrument that can keep the quality coherent. With a beautiful metaphor, the death of cause is an exhaling breath coming from an inhaling breath and going to another inhaling breath. It refers to a breathing rhythm for a dancing body and a dancing movement. To sum up, focusing on "a dynamic life of cause" pioneers another way to think of "cause composing" instead of "gesture composing".

**Conclusion**
As mentioned before, the different way to implement computer-choreographer communication is the fundamentals of seeing or doing: one from the result; the other from the cause. The authors propose "a dynamic life of cause", focusing on the birth, the growth and the death of cause. The methodology, based on mass-spring based modeling, exhibits energetic succession and connects well dance, physics and computer. A library of physics-based models, served by "a dynamic life of cause", has been created. It is convincingly a well-suited direction for computer-assisted choreography. The future work will involve in predicting human behavior by these models. Furthermore, the models will validate reversely the cause (pre-movement) with the purpose of movement understanding.

Finally, dancers exercise their body everyday in the aim to discover and rehearse how the motion of the whole is duly evolved from their motor locus. As quoted from Isadora Duncan: "I was seeking and finally discovered the central spring of all movement, the crater of motor power...", the authors seek for the cause, i.e. central spring, to generate dance movements and keep respecting dynamics during all the process.

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